

1 **PROCESS FOR MAKING A CURVED PREFORM MADE FROM WOVEN**
2 **COMPOSITE MATERIALS**

3
4 **BACKGROUND OF THE INVENTION**

5
6 Field of the Invention

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8 (001) The invention relates to the field of composite structure fabrication
9 techniques and, in particular, to a process for forming curves in woven
10 composite preforms.

11
12 Description of Related Art

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14 (002) Typically T shaped composite structures are fabricated by joining the
15 vertical member to the horizontal member by bonding a multi-number of
16 reinforcing sheets across the joint (extending from the horizontal member up
17 along the side of the vertical member). Such a joint is disclosed in WIPO
18 Publication WO 01/64387 A1 Production, Forming, Bonding Joining And
19 Repair Systems For Composite And Metal Components by N. Graham. Two
20 honeycomb sheets are joined by layers of composite cloth to the horizontal
21 member on each side of the vertical member that extend up each side of the
22 vertical member. The disadvantage is that the joint's strength is dependent on
23 the layers of composite cloth.

24
25 (003) Recently, three-dimensional weaving has allowed very complex shapes
26 to be woven. For example, US Patent No.: 6,007,319 Continuous Forming Of
27 Complex Molded Shapes by T. L. Jacobson, et al. discloses a method of
28 weaving complex preform shapes. More recently a process for making woven
29 3D PI cross-section shapes in US Patent No. 6,446,675 Minimum Distortion

1 2. Stretching the portions of the preform requiring curvature. If the preform
2 must be curved in the plane of the bottom foot portions with the first bottom
3 portion requires greater stretching than the second bottom foot portion, both
4 upstanding legs are bent over on to one of the bottom foot portions in a
5 “cactus” configuration. The preform is then placed between matched tapered
6 sign-wave dies, with a small amplitude end and a large amplitude end, with the
7 first portion positioned in the small amplitude end and the second end in the
8 large amplitude end. Stretching is accomplished by closing the die halves. If
9 the completed preform requires concave curvature of the bottom foot portions,
10 the bottom foot and upstanding leg portions of the preform are bent toward
11 each other in an “H” configuration, but only the upstanding legs are placed in a
12 small to large amplitude tapered sign wave die for stretching while the foot
13 portion is stretched at a constant amount in the large amplitude section of the
14 die. If on the other hand the bottom foot portions require a convex shape, the
15 bottom foot and upstanding leg portions are again folded together in an “H”
16 configuration. However the die shape is tapered over the length of the
17 upstanding legs from small to large amplitude and the foot bottom portions are
18 outside of the stretching sinewave die.

19 3. Forming the curvature in the preform. After the step of stretching, the
20 preform is expanded about a die surface having the final desired shape of the
21 preform.

22
23 (008) The preform can thereafter be used in the making of curved composite
24 structures, primarily as a transition member between sheet type structural
25 members. Note that the preform can be pre-impregnated with a resin prior to
26 any forming steps.

27
28 (009) It should be understood, that the above-described PI shaped preform
29 required that the threads in the direction of curvature be cut. However, it is
30 possible to make curved preforms that do not require this step. For example,

1 the preform could be manufactured with threads made from tows made up of
2 short discontinuous fibers. The "bundled" fibers act as a continuous thread
3 allowing their weaving into a preform, but also will allow stretching during sine
4 wave die forming. US Patent No.: 6,477,740 "Stretch Breaking Of Fibers" by
5 N. W. Hansen discloses a method of stretch braking of fibers of the thread.
6 discontinuous threads in the direction of curvature. Either method will work,
7 and the process would only comprise the steps of stretching and forming.

8

9 (010) The novel features which are believed to be characteristic of the
10 invention, both as to its organization and method of operation, together with
11 further objects and advantages thereof, will be better understood from the
12 following description in connection with the accompanying drawings in which
13 the presently preferred embodiment of the invention is illustrated by way of
14 example. It is to be expressly understood, however, that the drawings are for
15 purposes of illustration and description only and are not intended as a
16 definition of the limits of the invention.

17

18 **BRIEF DESCRIPTION OF THE DRAWINGS**

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20 (011) Figure 1 is a perspective view of the PI shaped preform made of woven
21 filamentary material.

22

23 (012) Figure 2 is a top view of the PI shaped preform shown in Figure 1
24 illustrating the effect of attempting to curve the preform in the "as is" condition.

25

26 (013) Figure 3 is a perspective view of the desired curved shape for the
27 preform shown in Figure 1.

28

1 (014) Figure 4 is an end view of the preform with the legs folded over on the
2 bottom portions installed in a darting die assembly.

3

4 (015) Figure 5 is a side view of the bottom portion of the die illustrating the
5 placement of the cutters used for darting the preform.

6

7 (016) Figure 6 is an enlarged view of a portion of the preform, after darting
8 illustrating the darting pattern.

9

10 (017) Figure 7 is a perspective view of a sine wave forming die assembly
11 used for selectively stretching the preform.

12

13 (018) Figure 8 is a cross-sectional view of the die assembly shown in Figure 7
14 illustrating a first method of stretching in order to form the preform shown in
15 Figure 3.

16

17 (019) Figure 9 is a cross-sectional view of a completed structure using the
18 preform shown in Figure 3.

19

20 (020) Figure 10 is a perspective view of the preform having a convex
21 curvature.

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23 (021) Figure 11 is a cross-sectional view of the die assembly shown in Figure
24 7 illustrating a second method of stretching the preform to obtain the curvature
25 shown in Figure 10.

26

27 (022) Figure 12 is a perspective view of the preform having a concave
28 curvature.

29

1 (023) Figure 13 is a cross-sectional view of the die assembly shown in Figure
2 7 illustrating a third method of stretching the preform to obtain the curvature
3 shown in Figure 12.

4

5 (024) Figure 14 is a perspective view of a second L shaped preform.

6

7 (025) Figure 15 is a perspective view of the preform shown in Figure 14
8 formed into a curved shape.

9

10 **DESCRIPTION OF THE PREFERRED EMBODIMENT**

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12 (026) The typical PI woven preform is illustrated in Figures 1 and 2, indicated
13 by numeral 10. The preform 10 includes upstanding legs 12 and 14 and
14 bottom foot portions 16 and 17, with center or root 18. The warp fibers 20 run
15 parallel to the legs 12 and 14, while the threads 21 run perpendicular to the
16 upstanding legs. If one tries to form a curve, indicated by arrows 22A and
17 22B, the legs 12 and 14 tend to bend over indicated by arrow 24. Attempts to
18 “bend” the preform 10 into other shapes also cause one or more portions to
19 warp. The subject process will eliminate this problem.

20

21 (027) A completed preform 10A is shown in Figure 3, having a curved length
22 26, with a radius 28. To accomplish this, the upstanding legs 12 and 14 are
23 pushed over onto the one of the bottom portions 16 or 17 as shown in Figure
24 14. The folded preform is then place in the die 30 shown in Figures 4 which
25 includes a cutter head 31 and an receiver pad 32. The cutter head 31
26 incorporates staggered blades 32 having a width 33 as shown in Figure 5
27 slightly greater than the width of the warp threads 20, allowing for some
28 mismatch in warp thread location. This allows the warp threads 20 to be cut
29 (darted) periodically into segments such that the cuts in each tread are spaced

1 from the cuts in the adjacent treads as shown in Figures 6. The spacing 35 of
2 the cuts should be as large a distance as possible, but still allowing the curved
3 length 26 to be formed. Thus some experimentation may be required to
4 obtain the optimum spacing.

5

6 (028) Referring to Figures , if the part is to be simply curved shape as shown
7 in Figure3, the darted preform 10 is folded as shown in Figure 14 Cactus with
8 the legs 12 and 14 bent over on to leg 16. The preform 10 is placed in a sine-
9 wave shaped die assembly 40 having matched die halves 41 and 42 with
10 mating sign-wave shaped forming surfaces 43 and 44 respectively. The sign-
11 wave pattern is on forming surface 43 is tapered from ends 45 and 46 on die
12 half 41 and the forming surface 44 is tapered from ends 47 and 48 on forming
13 surface 44. What the sine wave forming accomplishes is a stretching that is
14 zero at the end of bottom portion 17 and a maximum at the end of bottom
15 portion 16.

16

17 (029) The now stretched preform 10 can be placed in a die assembly (not
18 shown) and formed into its final shape. Alternately the stretched preform can
19 be shaped by hand. Referring to Figure 9, it can thereafter be resin infused by
20 any of several existing resin infusion processes and be used to join to
21 structural elements together. For example, structural elements 52A and 52B,
22 by the process set forth in WIPO Publication WO 01/64387 A1 Production,
23 Forming, Bonding Joining And Repair Systems For Composite And Metal
24 Components by N. Graham. Of course, the preform could be resin infused
25 prior to darting and stretching.

26

27 (030) If the completed preform requires curvature in a convex shape as
28 illustrated in Figure 10 and designated by numeral 10B, the preform 10 is
29 folded the shape as illustrated in Figure 11 with the legs 12 and 14 folded
30 together and portions 16 and 17 folded together. As illustrated the die halves

1 41A and 42A have forming 43A and 44A. Stretching would only from the
2 center outward toward the end of the legs 12 and 14 where stretching would
3 be at a maximum.

4

5 (031) If on the other hand, the preform final shape shown in Figure 12, and
6 designated by numeral 10C, is desired, then, as illustrated in Figure 13, the
7 legs 12 and 14, and portions 16 and 17 are brought together as in the previous
8 example, and placed in the die assembly 40B having die halves 41B and 42B
9 with forming surfaces 43B and 44B. However, stretching is accomplished by
10 placing the folded preform 10 in the sine-wave dies such stretching of the legs
11 12 and 14 is a minimum at there ends and becomes a maximum at the center.
12 Thereafter, stretching of the bottom portions 16 and 17 is held constant.

13

14 (032) Thus it can be seen that the process will allow the PI shaped preform to
15 molded into numerous curved shapes, many more than have been described
16 herein. While there is a weakening of the preform due to the cutting of the
17 warp fiber, the loss of strength has proven acceptable in most applications,
18 particularly where the primary loads and distributed along the fill fiber.

19

20 (033) It should be understood, that the above-described PI shaped preform
21 required that the threads in the direction of curvature be cut. However, it is
22 possible to make curved preforms that do not require this step. For example,
23 the preform could be manufactured with threads made from tows made up of
24 short discontinuous fibers. The "bundled" fibers act as a continuous thread
25 allowing their weaving into a preform, but also will allow stretching during sine
26 wave die forming. US Patent No.: 6,477,740 "Stretch Breaking Of Fibers" by
27 N. W. Hansen discloses a method of stretch braking of fibers of the thread.
28 The thread thereafter can be used to weave preforms. Illustrated in Figure 15
29 is a right angle preform, generally indicated by numeral 60, having horizontal
30 leg 62 and vertical leg 64, while illustrated in Figure 16 is preform, now

1 indicated by numeral 60A formed into a curved shape. Such a preform 60
2 could be formed by folding the vertical leg 64 over and on to the horizontal leg
3 62 and forming in a die assembly similar to one shown in Figure 8..

4

5 (034) While the invention has been described with reference to a particular
6 embodiment, it should be understood that the embodiment is merely
7 illustrative, as there are numerous variations and modifications, which may be
8 made by those skilled in the art. Thus, the invention is to be construed as
9 being limited only by the spirit and scope of the appended claims.

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11 **INDUSTRIAL APPLICABILITY**

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13 (035) The invention has applicability to industries manufacturing composite
14 structures, particularly, the aircraft industry.